Historic, Archive Document

Do not assume content reflects current scientific knowledge, policies, or practices.

No. 3054

MECHANIZATION OF SUGAR-BEET PRODUCTION

By E. M. Mervine and S. W. McBirney
Division of Mechanical Equipment
Bureau of Agricultural Engineering

Economical growing of sugar beets has been difficult because of the cost in dollars and cents and also because the hand labor involved has made the job undesirable. The solution to the problem has been to mechanize the two peak labor loads, one in the spring of the year at "thinning" time and the other at harvest.

Most of the effort in the past has been directed toward the harvest job. Considerable progress has been made. Some mechanical harvesters have given evidence of doing the job when the conditions are not too severe, and a paper analysis of some combination schemes makes it look as if that end of the beet growing season could be taken care of.

The idea of mechanizing the thinning operation has not been given much consideration until very recently. Now it looks as if the beet crop might be grown without any of the "stoop" labor, with the costs reduced materially and with the elimination of the serious problems involved when importing labor.

The cost of harvesting, as now practiced, varies with the size or tonnage of the crop and with the conditions under which the grower has to work. This is illustrated by the fact that in California the crop is harvested only as fast as the factory will take the beets for processing. In the Middle West and in the mountain states the beets must be taken from the field before there is danger

---

Presented before the annual meeting of the American Society of Agricultural Engineers, St. Paul, Minn. June 22, 1939.

of their being frozen in the ground. This latter method necessitates the harvest being hurried. The digging of the beets must be postponed as long as possible in order to secure the maximum sugar yield and at the same time the harvest must be finished before severe freezing. It also means that the beets have to be stored until the factory can process them.

Let us assume a fifteen ton crop for Colorado conditions. The costs may be estimated for a variety of different methods of harvesting. Some of these schemes, such as the present hand method, have been tried. Some have been tried experimentally to the extent that a fairly accurate estimate of costs can be made. Other systems have been proposed but never tried to the extent that costs could be determined; their estimates can be based only on judgment.

Table 1.- Present and Proposed Harvesting Systems, Based on a 15-ton crop

	Costs per Acre
Present hand methods	$ 20.80
Mechanically lift, hand top in field, mechanically load	8.81
Central topping plant	20.81
Mechanically lift, top, load	9.00
Mechanically lift, hand top on machine, mechanically load	8.27
Mechanically top in place, mechanically lift, hand load to mechanical elevator	12.36
Mechanically top in place, mechanically lift, single row, hand load	10.26

This series of assumed costs may be subject to considerable alteration as more experience shows where one cost might be raised and another might be lowered. Still the extreme differences plainly indicate the possibilities of

mechanizing the harvest operation. Also they indicate that a compromise system in which some hand labor combined with a machine might be even better than a strictly machine operation.

These costs are supposed to cover everything, such as machinery depreciation and repairs as well as labor and power. They also take into account the fact that different methods yield different qualities of product. This is illustrated by the fact that the beet tops are valuable as cattle feed. In some of these harvesting methods the tops are left in better shape for such feed than they are by some of the other methods. The listed costs are net after crediting the value of tops to the operation.

Mechanical thinning has been considered an impossibility, but from an engineer's point of view it looks not only possible but quite practical. For four years now beets have been mechanically thinned experimentally. Not only has the stoop labor been eliminated in these trials but the product gives evidence of being equal to the hand-produced crop. In fact, there have been times when the product has been larger than the hand-thinned crop. During the past year the entire sugar industry has accepted the idea and is now calling for early adoption of it.

Beet seed balls contain one or more germs averaging about three in the imported seed which has been rather universally used until very recently. During the past few years the amount of home grown seed has been on the increase until now it looks as if we would soon be using United States grown seed entirely. This seed is, in general, smaller than the foreign seed and has fewer germs per seed ball. This characteristic fits in with the mechanical thinning idea nicely because a larger percentage of the seed balls will result in an increased number of single seedlings. Many of the seed balls will sprout only one seedling even though there may be more than one germ present.

harvesting the correct operation. Also they indicate that a harvesting system in which some hand labor combined with a machine might be even better than a strictly machine operation.

These costs are computed to cover everything, such as machinery depreciation and repairs as well as labor and power. They also take into account the fact that different methods yield different qualities of product. This is illustrated by the fact that the beet tops are valuable as cattle feed. In some of these harvesting methods the tops are left in better shape for such feed than they are by some of the other methods. The listed costs are net after crediting the value of tops to the operation.

Mechanical thinning has been considered an impossibility, but from an engineer's point of view it looks not only possible but quite practical. For four years now beets have been mechanically thinned experimentally. Not only has the stoop labor been eliminated in these trials but the product gives evidence of being equal to the hand-produced crop. In fact, there have been times when the product has been larger than the hand-thinned crop. During the past year the entire sugar industry has accepted the idea and is now striving for early adoption of it.

Beet seed balls contain one or more germs averaging about three in the imported seed which has been rather universally used until very recently. During the past few years the amount of home grown seed has been on the increase until now it looks as if we would soon be using United States grown seed entirely. This seed is, in general, smaller than the foreign seed and has fewer germs per seed ball. This characteristic fits in with the mechanical thinning idea nicely because a larger percentage of the seed balls will result in an increased number of single seedlings. Many of the seed balls will sprout only one seedling even though there may be more than one germ present.

Customary planting has, to a certain extent, bunched the seed balls with the result that seedlings have been bunched and then there would be skips in the row. A measure of desirable planting is to use a scale along the row, marked in one inch graduations, so that it is possible to say how many of the one inch spaces have, within it, one or more beet seedlings. This can be expressed by saying that a certain percentage of the inches in the row contains seedlings. This may be a measure of distribution of plants in the row, not necessarily the number of singles. A further measure of the planter's ability may be expressed as the number of these beet-containing inches which have singles. Thus a strip of beets one hundred inches long may have 45 inches in which there are beets; this would be described as a 45 percent stand. Perhaps nine of these inches would have only single beets or there would be only 9/45 or 20 percent of the beets as singles.

It is readily possible to mathematically determine the number of single beets which would be left in the field and how far apart they would be when such a field would be mechanically blocked. Blocking knives and spaces may be spaced so that the desired number of singles will be left in the field. Under such conditions there would also be left in the field a number of bunches. These bunches could be cut out by the use of a long-handled hoe and the desired singles left. Such a process would eliminate the commonly used stoop labor which now crawls on hands and knees doing the necessary hand thinning. This process has been accomplished experimentally on standard plantings.

Single Seed Ball Sugar Beet Planting

Cooperative research by the Bureau of AgriculturalEngineering and the Agricultural Experiment Stations of California and Colorado, on the mechanization of sugar-beet blocking and thinning, showed the desirability of a more uniform distribution of seedlings in the row. An ideal stand for mechanization

Mechanical thinning does, to a certain extent, forestall the seed balls with the result that seedlings have been treated [illegible] then there would be gaps in the rows. A measure of down-the-row thinning is to use a knife along the row, placed in the seed [illegible], so that it is possible to cut out many of the one seed [illegible] spaced seeds, without [illegible] more than seedlings. This can be expressed by saying that a certain percentage of the knives in the row contains seedlings. This may be a measure of distribution of plants in the row, and necessarily the number of singles. A further measure of the precision [illegible] may be expressed as the number of those [illegible] which were singles. Thus a [illegible] of knife [illegible] which [illegible] this would be described as a 15 percent [illegible]. [illegible] would [illegible] only single [illegible] would be only [illegible] percent of the [illegible] as singles.

It is readily possible to mathematically determine the number of single beets which would be left in the field and how far apart they would be when such a field would be mechanically thinned. Blocking knives and spaces may be spaced so that the desired number of singles will be left in the field. Under such conditions there would also be left in the field a number of bunches. These bunches would be cut out by the use of a long-handled hoe and the desired singles left. Such a program would eliminate the commonly used stoop labor which has proved so costly and [illegible] the necessary hand labor. This process has been accomplished economically on numerous plantings.

Single-Seed with Sugar Beet Planting

Cooperative research by the Bureau of Agricultural Engineering and the Agricultural Experiment Stations of California and Colorado, on the mechanization of sugar-beet blocking and thinning, showed the desirability of a more uniform distribution of seedlings in the row. An ideal would be the accomplishment

would be one having single seedlings regularly spaced every inch or two in the row. However, such stands are not possible with sugar-beet seed because of the multiple-germ nature of the seed balls. Bunching of seedlings has been more or less attributed to multiple-germ balls rather than to bunched seed when planting.

Experimental plots were carefully put in by hand to determine whether it was multiple-germ balls or bunched seed which produced bunched seedlings. These plantings with exact spacings of one seed ball per inch resulted in much more uniform germination stands than those obtained with commercial planters. The hand-planted plots had larger numbers of single seedlings. The total number of seedlings was spread into a greater percentage of the inches of the row, thus resulting in a smaller average number of seedlings per beet-containing inch, conditions more favorable to mechanization of the thinning of the crop. Germination tests in a seed laboratory, where conditions were kept ideal, showed a maximum average of from 2.0 to 2.75 sprouts per seed ball on large-sized, viable seed and an average of around 2 or slightly over for the larger sized, sack-run seed. Large sized seed in the field under favorable germination conditions produced an average of approximately 1.75 to 2.25 sprouts per seed ball. Evidently the bunching of seedlings obtained with commercial planters is largely due to bunching of seed balls.

Considerable preliminary research was carried on with the more promising types of existing commercial planters to learn if they could be adapted to satisfactory single seed planting.

None seemed to have a uniformity of seed drop which approached what was desired. Other types of seed-feeding mechanisms were investigated to discover one which would drop single seed balls and which, if possible, in addition could be used with any sized commercial seed, thus eliminating the necessity of grading the seed. The pick-up cup or cell type of mechanism seemed to show the most

promise and a single row unit was built embodying this principle. It utilized an endless chain of small seed cups passing up through a seed hopper where one ball was picked up in each cup. The cups emerge from the surface of the seed and allow all surplus balls to fall away. They then enter a tube which confines the balls between the cups and pass over the driving sprocket and down to the bottom of the opened furrow where the seed balls, still equally spaced, are dropped. The seed spacing could be easily varied by changing the travel of seed chain relative to the forward travel of the planter. Tests where seed balls were dropped onto a floor with this unit showed that approximately the desired uniform spacing of the seed balls was being obtained.

Several sets of experimental plots were put in with this single row, hand planter unit and with a conventional planter in 1937. Seeding rates varied from 5 to 20 pounds per acre. Comparative hand plantings were also put in, one seed ball per inch, which, with the seed used, gave a rate of 14 to 15 pounds per acre. Germination stand counts were made on the plantings and are listed for the three types of planting at the 14- to 15-pound seeding rate in the following table.

Table 2 .- Germination Stand Counts (14 to 15 pounds of seed per acre.)

Planter	Seedlings per 100 inch.of row	Percent of inches with beets	Singles per 100 inches
Conventional	121.7 ± 4.9	54.7 ± 1.3	14.0 ± .6
Single Seed	127.0 ± 3.3	67.2 ± 1.3	21.3 ± .8
Hand Planted	131.6 ± 7.4	72.8 ± 3.4	23.9 ± 1.2

Though there is some difference in the number of seedlings per hundred inches of row as shown in the first data column, those differences are not significant. This is logical as with comparable germination conditions equal amounts of seed should produce similar numbers of seedlings. The differences are probably due to slight variations in seed rates. However, the seedlings were spread into a greater percentage of the inches of row when the seed was planted with the single seed planter than when a conventional planter was used as shown in the next column of the table. This difference is highly significant. The hand planting is still better but not significantly better than the single seed planter. The last column shows the number of single seedlings, that is, inch lengths of row which contained a single seedling, per hundred inches. The single seed planter produced half again as many singles as did the conventional planter, a difference which is highly significant. Again, the difference between the single seed planter and hand planting is not quite significant though nearly so in this latter case.

The different plantings at the different seeding rates all showed better germination stands for the single seed planter unit than for the conventional planter, and the differences for each planting rate were significant. The percentage stands with the single seed planter increased from 30 percent for the 5-pound seeding rate to 73 percent for the 20-pound seeding rate while with the conventional planter the corresponding percentages increased from 26 percent to 59 percent.

After-thinning stand counts showed that reasonably satisfactory hand thinned stands were obtained with seeding rates as low as five pounds per acre with the single seed planter while the after-thinning stands obtained with the conventional planter at that seeding rate were not satisfactory.

The results with this single row, chain feed, pick-up cup, single seed planter were so encouraging that a six-row, tractor-drawn planter using the same

type of planting mechanism was built for the next year's planting season (1938). This planter is shown in Figure 1 and the details of one of the single row units are shown in Figures 2 and 3. This machine was used for several experimental plot and field strip plantings during the past two seasons.

A simpler pick-up cup type of single seed planting mechanism was used in another experimental planter which was also built for the 1938 planting season. It consisted of a pressed steel disk of pick-up cups attached to the inner side of one of the disk opener disks. These cups pick up seed from a supply carried in a small secondary hopper formed in the disk opener casting. The planter and details of its mechanism are shown in Figures 4 and 4a. Several experimental plot and field plantings have also been put in with this planter during the past two seasons.

In addition to the two types of single seed beet planters being developed by the Bureau of Agricultural Engineering and its cooperators, several manufacturers and individuals have been interested in the development of such equipment. One manufacturer of beet planters adapted one of its plate planting mechanisms to a runner opener drill in such a way as to decrease the distance of seed drop to approximately seven inches and used special small-celled, single seed plates and special seed cut-offs and knockers or dislodging devices. Several of these experimental planters were built for use in the 1938 season.

Another experimental single-seed planter tried out in 1938 was built by one of the sugar company representatives. This planter utilized a horizontal axis, vertical seed plate or wheel with a double row of seed cells cut in the edges of its rim. The cells picked up seed balls as they passed through the bottom of the hopper, carried them down and dropped them into the bottom of the opened furrow. To minimize the distance of seed drop this seed wheel was mounted in a runner type of furrow opener. Development is being continued on this type of planter by the sugar company interested.

Other manufacturers are experimenting with new devices and adaptations of present planters for single seed planting. In fact, development of this type of beet planting equipment is progressing so rapidly that considerable time is now being devoted to devising some simple, yet adequate, method of testing these planters and of working out the best methods of utilizing this type of planting for further and more complete mechanization of the blocking and thinning operations.

Up until this past winter the method of comparing single seed and conventional planters has been by using field germination stand count data as a criterion for comparison. As data to make satisfactory direct comparisons of uniformity of seedling spacing would be so lengthy and would require such a tremendous amount of work in the office, a simpler method of comparison has been used. It is based on the assumption that with a given number of seedlings per hundred inches, the planter, which spreads those seedlings into the greatest number of inches of row, or, in other words, has the smallest number of seedlings in each beet-containing inch, is the one doing the most satisfactory planting. In other words, the planter doing the best work is the one which secures the highest percent stand for a particular seedling stand. Direct comparisons between planters can only be made with the same seedling stands or seeding rates and for practical comparisons of planters curves with percent stands plotted against seedling stands must be used.

The method of comparing planters just described takes three to four weeks after planting, often longer, depending on germination and growing conditions following planting. In addition it introduces the variable of germination which is important and necessitates a number of separate counts to get a reasonably good average. Then, too, if seedling stands are not the same for the two planters being compared, direct comparisons cannot be made.

This past winter a laboratory means of testing beet planters and making comparisons of the uniformity of their seed drop was developed. It consists of pulling the planter being tested along a slightly raised runway at planting speed and with the openers down in planting position and cataching the seed dropped on boards covered with a thin coating of light weight cup grease. The boards are set so that they are just cleared by the furrow openers, and the distance of seed drop is therefore only slightly more than it would be in field planting. The seed balls are caught and held at the exact point where they strike. Such a surface is not comparable with the narrow bottom of the opened furrow into which the seeds are dropped in the field, but it overcomes all bounce or roll of the seed and provides a means of comparison of uniformity of seed drop.

The grease is much more readily removed and the boards prepared for another run than with many other sticky materials that might be used. The boards were painted a flat black to provide a contrast with the seed for photographing. Figures 5 and 6 show the test setup and a sample drop from the chain-feed single-seed planter.

A flexible steel tape is laid down on the board alongside the row of seed dropped in each test and the longitudinal position of each seed is recorded. A run and a check run, each 200 inches, were made for each test setup. From an original set of data sheets the frequencies of seed spacings were tabulated and a curve made up showing the percentage frequency of each seed interval observed in the tests. Such curves, with the mean seed spacing also shown, gave a graphic comparison of the seed drop of the planter. Figure 7 shows a sample of one of the most uniform seed distributions obtained with any of the single seed planters while Figure 8 shows a corresponding curve of a typical conventional plate planter. The percentage of the frequencies within a plus

and minus band about the mean was used as a numerical value for comparison of the work of the planters. For our work we used the interval of plus and minus one-fourth inch from the mean. Direct comparisons can only be made between tests with practically the same mean seed spacing as the percentage of frequencies within the band about the mean increases for a planter as the seeding rate increases.

The averages of the data taken in a series of laboratory tests such as described above gave the following results.

The seed drop of the chain-feed single-seed planter was significantly more uniform than that of the other single-seed or conventional planters as a group or than any of the planters as individuals. The single-seed planters were significantly better than the conventional planters. There were no significant differences between the single seed planters other than the chain-feed planter nor between the conventional planters though larger numbers of test runs might show differences which were significant.

On plate planters there was a tendency toward more uniform seed distribution with the single-seed plates as the distance of drop decreased, but not enough for significance or near significance. With conventional plates whose cells drop 12 to 15 seed balls there is a significant decrease in uniformity of seed distribution as the distance of drop decreases, particularly from a 25-inch drop to a 7-inch drop. With a 34-inch drop there was no significant difference between conventional plates and single seed plates though the latter tended to be better and increased numbers of tests would probably show this tendency to be significant.

Field tests with the single seed and conventional planters show substantially the same results though the differences between the chain feed and the other single seed planters is not so marked. Seed balls undoubtedly bounce or roll around somewhat as they drop into the bottom of the opened furrow so that very uniformly spaced seed dropping into the bottom of a furrow would

probably lose some of the uniformity of spacing. Furthermore, seedlings do not grow vertically from the seed balls, but rather follow paths of least resistance so that seedlings from very carefully spaced seed balls do not have the uniformity of spacing of the balls. For these reasons the significant difference between the chain-feed and other single-seed planters as shown by the greased board laboratory tests, becomes less significant in field comparisons. We are therefore probably not justified in developing elaborate planting mechanisms for obtaining single-seed planting.

The single-seed planters as a group show significant improvement in uniformity of field stands over conventional planters. They produce the same percentage stands with slightly over 90 percent of the amount of seed required for conventional planters, or they produce from four to five percent greater percentage stands at the same seeding rates over the usual range of seeding rates. They also produce 20 percent to 30 percent more single seedlings, some trials having run up to nearly 50 percent more singles than conventional planters.

The differences between most of the single seed planters are not great. The chain feed pick-up cup planter, though doing somewhat better work is more complicated, and the additional cost of its manufacture perhaps is not justified. The work of the experimental single-seed planters with pick-up cup disks or wheels, as compared with horizontal plates or with vertical wheels showed no significant differences. Furthermore, a standard plate planter equipped with special single-seed plates, seed cut-off and knocker and with its normal 34-inch seed drop did practically as well as the same type of equipment in the single-seed planter with its low hoppers. This means that new type planters are probably not needed for satisfactory single-seed planting and that conventional plate planters equipped with the proper special equipment, such as single-seed plates, with adapted seed cut-offs and knockers and more or less straight, nearly vertical seed tubes from seed hoppers to furrow openers, will be satisfactory for commercial single-seed planting.